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Foraminiferal and sediment geochemistry studies in and around Cochin backwaters, southwest coast of India

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Based on the foraminiferal studies, 25 foraminifera taxa belonging to 16 genera, 13 families, 10 superfamilies, and 6 suborder have been identified. Various sedimentological parameters such as $CaCO_3$, Organic matter and sand-silt-clay ratio were determined for the samples in order to study the relationship between substrate and foraminiferal populations, and to evaluate the favoured substrate of dominant species populations. Foraminiferal assemblages are more in the silty sand and sand substrate environments. Based on the foraminiferal distribution, in the upper part of the estuary, species diversity are very rare in abundance due to the tidal fluctuation the species are distributed in this region. In the middle estuary due to the mixing of estuarine and marine influence, the diversity is lesser in amount. In the lower estuary near the seashore the species diversity is slightly higher than the middle estuary due to the salinity influence and the open ocean conditions.

[Keywords: Foraminifera, distribution, ecology, Cochin backwater, Kerala**]**

Introduction

Microfossils are fossils generally smaller than one millimeter and not larger than four millimeters in size. Foraminifera have wide applications in stratigraphic correlation, higher resolution biostratigraphy, oil exploration, environmental and paleoenvironmental interpretations[1]. Foraminifera have been successful inhabitants of every aquatic environment from deep oceans to brackish water, lagoons, estuaries and even rarely in freshwater streams, lakes etc. Geochemical studies of surface sediments along the Indian coast have been extended in the last few decades due to the growing awareness of coastal pollution and its impact on the ecosystem.[2-5] Various studies have demonstrated sediments from coastal areas greatly contaminated by heavy metals; therefore, the evaluation of metal distribution in surface sediments is useful to assess pollution in the marine environment[6] In addition, studies on recent foraminifer’s fauna from the seas and other marine marginal water bodies of India, especially along the west coast have done by several workers[7-11].But the distributions of foraminifera along the SW coast of India have to be still explored in detail. In order to know their distribution in different habitats off Cochin Backwaters of Kerala, the present study has been taken up to enhance the existing knowledge on foraminifera of west coast of India.

Materials and Methods

The Cochin back water is a part of the largest lake in Kerala, the Vembanad Lake (Lat 9 28’ and 10^0 10’ N and Long 76^0 13’ and 76^0 30’ E). It is a shallow tropical estuarine system of about 270 square kilometres located in the southwest coast of India. Hydrographically the area subjected to changes depending on the seasons. Climatologically, the annual cycle consists of the pre-monsoon (March), monsoon (June and October) and the post-monsoon seasons (November to December). It is influenced by the southwest monsoon from about the middle of May to August and by some precipitation from the northeast monsoon during October- December.

As a prelude to sample collection a base map was prepared using Toposheets (1:50,000) from survey of India. All the prominent and permanent objects, rivers, tanks, roads and elevation were marked in the base map. In order to study the distribution of recent benthic Foraminifera in back waters, surface sediment samples were collected from the backwaters of Cochin, with the help of a motor launch. The locations of surface samples are recorded using GPS. Thirteen surface samples were collected from backwaters and mangrove swamps. All the sediment samples were analysed to standard micropaleontological techniques[12,13]. So as to record the occurrence of foraminifera. Calcium carbonate, and organic matter in the sediment samples were determined by adopting a methodology suggested by Piper[14], Gaudette et al., [15] Walkey-Black16 adopted and modifiedby Jackson[17] respectively. Sand, silt and clay percentages were calculated using a combination of sieving and pipette procedure, the later in accordance with Krumbein and Pettijhon[18] (Trilinear plots were prepared and description has been given based on Trefethen's[19] textural nomenclature.

The handpicked faunal specimens from each sample were transferred to 24-chambered micropaleontological slides and mounted over a thin layer of tragacanth gum according to the family, genus and species, wherever possible. The different genera and species were identified; type specimens of each species were selected and transferred to round punch microfaunal slides with cover slips. Later, they were mounted on brass stubs (1 cm in diameter) using a double-sided adhesive carbon tape and coated with palladium for about 90 to 120 seconds (JEOL: JFC) ion sputtering device) to render the

surface of the foraminiferal tests conductive for scanning. To obtain lucid illustrations, microphotographs of different views of all the foraminiferal species present were taken using a Scanning Electron Microscope (JEOL JSM-6360). All the foraminifera species described and illustrated here are deposited in the Department of Geology, University of Madras, Chennai.

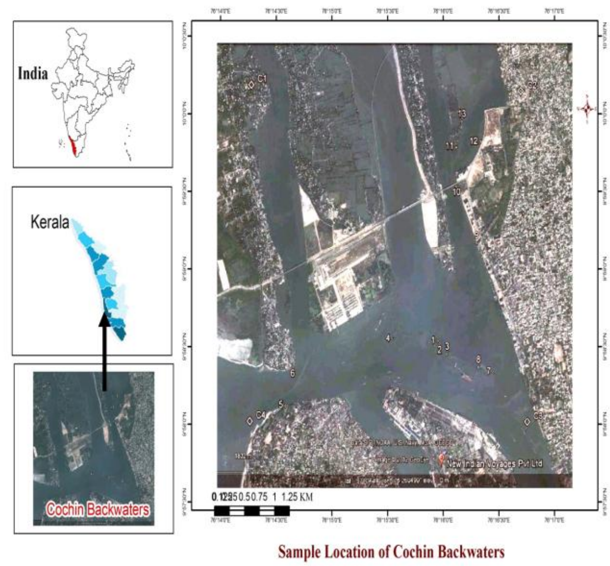

Figure 1. Location Map

For total digestion the geochemical analytical procedure suggested by Shapiro and Brannock[20] were followed. For total or residual trace metal analysis, the solid was digested with acid mixture. For a 0.5g (dry weight) sample, the sediment was first digested in a Teflon beakers with 25ml of acid mixture (HF 360ml, 60:60 H_2SO4, and 20ml of perchloric acid) to near dryness; subsequently a second addition of 10ml acid mixture was made and again the mixture was evaporated to near dryness, until the appearance of white fumes. To the residue 5ml of HNO3 and 50ml of distilled water are added and make up the residue into 100 ml. The solution was finally analyzed for total Fe, Mn, Cr, Cu, Ni, Co, Pb, and Zn on a PerkinElmer AA 700 AAS equipped with a deuterium background corrector.

Results and Discussion

The classification proposed by Loeblich and Tappan[12] has been followed in the present study through which 25 foraminifera taxa belonging to 16 genera, 13 families, 10 superfamilies and 6 suborder have been identified (Table.1). Study of foraminifera began as an investigation into their taxonomy and the purely descriptive phase of foraminiferal studies is gradually giving way to ecological investigations. Identification of the species recorded in this study is based on comparison with the Catalogue of Foraminifera by Ellis and Messina[21] onwards, innumerable publications and several researchers from all over the world) and specimens reposited in the Department of Geology, University of Madras, Chennai- 600 025, India.

Table.1. Taxonomy of Foraminifera in the Cochin back water.

Order	**Suborder**	**Superfamily**	**Family**	**Genus**	**Species**
Foraminiferida	Rotalina	Rotaliacea	Rotaliidae	Ammonia	*A.beccarri*
					A.tepida
				Asterorotalia	*A.dentata*
					A.inflata
			Elphididae	Elphidium	*E.advenum*
					E.discoidale
					E.incertum
					E.crispum
		Bolivinacea	Bolivinidae	Bolivina	*B.striatula*
					B.nobilus
		Discorbacea	Bagginidae	Cancris	*Cancris auricula*
	Globigerinina	Globigerinacea	Globigerinidae	Globigerina	*G.bulloides*
		Globorotaliacea	Globorotaliidae	Globorotalia	*G.minardii*
		Orbitoidacea	Amphisteginidae	Amphistegina	*A.radiate*
	Lagenina	Nodosariacea	Lagenidae	Lagena	*L.laevis*
	Miliolina	Miliolacea	Miliolidae	Miliolinella	*M.circularis*
			Hauerinidae	Quinqueloculina	*Q.intricata*
					Q.seminulam
				Triloculina	*T.trigonula*
					T.tricarinata
			Nubeculariidae	Spiroloculina	*S.communis*
					S.depressa
	Textularina	Lituolacea	Textulariidae	Texularia	*T.earlandi*
			Trochamminidae	Trochammina	*T.inflata*
	Nonionacea	Nonionacea	Nonionidae	Nonionoides	*N.elongatum*

According to Albani and Johnson[22] the composition of a living assemblage affects environmental conditions which exist at the time of sample collection. In order to find out whether the organic matter and calcium carbonate contents of the sediments and the nature of substrate reflect the environmental conditions of foraminifera, an effort has been made to determine the same in all the sediment samples collected from the Cochin backwaters of southwest coast of Kerala.

The organic matter content in the sediments of surface samples ranges from 0.97 to 8.37 % (fig. 2). The lowest value 0.97% was recorded in station no.1 at a depth of 0.5 m and the highest value 8.37% in station no 9 at a depth of 1.7m. In the study region, the organic matter are higher in the samples no 4, 9, 10, 11, 12 and 13. This may be due to the waste disposal from urban sewage, and the decay of plants. Organic matter is slightly decreased near the sea bar mouth region may be due to the current action there will be no deposition of organic material. Sandy sediments have been found to be poor in organic matter content, while fine-grained materials are rich, the relation shows in figure 3.

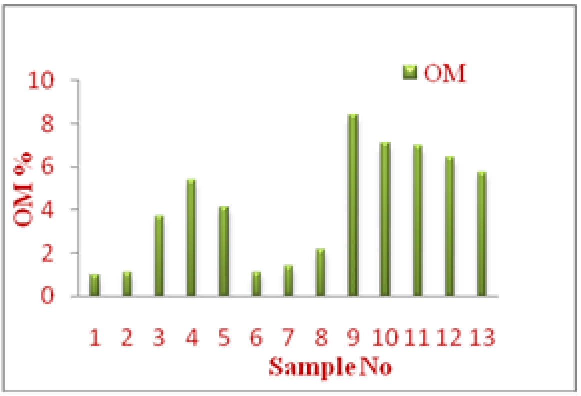

Fig. 2 Distribution of Organic Matter

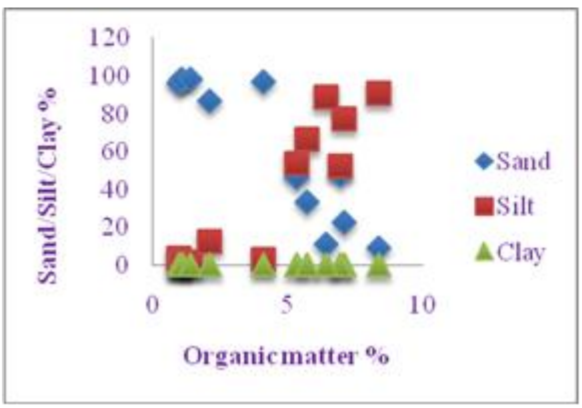

Fig.3 Organic matter Vs substratum

In the present area, it has been found that the calcium carbonate percentage in the surface sediments of Cochin backwaters varies from 0.5 % to 5.5 % (Fig.4). The calcium carbonate value is high in station no 6, which is at a depth of 0.2m. When megascopicaly checked, higher orders of broken shells are noticed and further, this station is near to river mouth. Due to the salinity influence the species assemblages are high. Further the species *A.beccarri* and *A.tepida* are tolerating wide range of salinity and temperature fluctuation[23]. The significant variation in the distribution of total and living assemblage may be due to the rate of sedimentation as need as due to postmortem transport of tidal current[24]. This is also a reason for the higher rate of calcium carbonate. The presence of broken shells mixed up in the sand in this area is also expected to cause a rise in the carbonate content. The low value of calcium carbonate in this region is mainly due to the non deposition of broken debris in that region due to the tidal action.

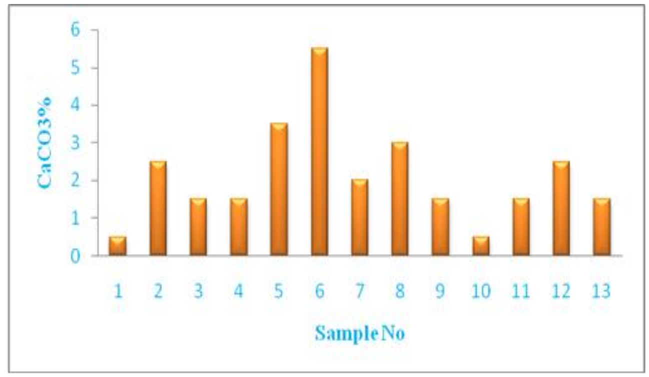

Figure. 4. Distribution of Calcium Carbonate

The relative abundance of sand, silt and clay in the sediments of surface has been estimated. The determined values are plotted on trilinear diagrams. Trefethen's[19] textural nomenclature has been used to describe the sediment types of the present area. Taking into consideration the 12 possible sediment types of Trefethen (op. cit.), the substrate of the Cochin backwaters of surface samples consists of sand, sandysilt and silt (Fig.5). As a whole, the sediment of the Cochin backwaters appears unfavourable for the thriving of the standing crop. However, fine grained substrate such as silt, sandysilt and siltysand are found to be the most accommodative sediment type.

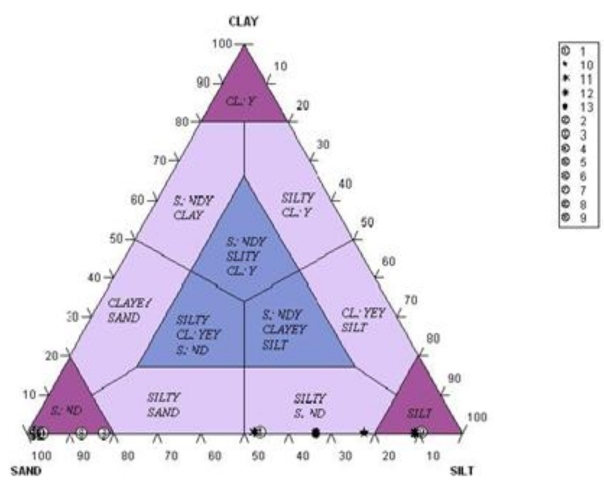

Fig.5. Trilinear plots of Sand Silt Clay ratio of backwaters of Cochin

In the study region, the near shore marine sediments clay dominates over the others. This clearly shows that fine sediments gradually increases from river to marine area. While studying the sediment and organic carbon distribution in the Cochin harbor area, Seralathan et al.,[25] have stated that within the last two decades the supply of coarse clastics in the estuarine region is considerably reduced after the commissioning of several bunds and dams. Further, because of increased organic input in association with fine clastics, reducing condition prevails the color of the bottom sediment exhibit uniformly olive gray. The water content of the sediments gradually decreases with depth due to compaction. Siltation caused by river discharge and the resulting tidal influx has a major factor contributed for the decrease in the depth of the backwater. From the available data, it has been deduced that in the course of 50 year, average depth of the estuary has been reduced from 6.7m to 4.4m [26] Studies on the sedimentation rate showed a deposit of 0.2 cm/year[27]. Rivers joining the backwaters contribute towards siltation in the region[28].Considerable silting takes place in the channels in the mouth region as they lie on the convex side and become the natural intake and repository for inborn silt of the flood tide. The ebb tide is not able to remove the material coming in. Thus the material from the sea bed is distributed by wave action and transported by the flood tide from the main source of silting in the mouth[28]. On account of this, an estimated 2.5 million cubic yards of sediment per year is dredged out from the channels[29.] Studies also revealed that there existed a substantial variation in mixing due to the deepening and widening of the channels[30] . Silt and clay on the sea bed are distributed by the heavy wave action and thus accounts for the increase in silt content during monsoon.

Geochemical analyses for Mn, Cr, Cu, Co, Ni, Pb and Zn were carried out and their mean concentration is listed in Tables 2.

Table.2. Trace element distribution in the study area

Sample.NO	Fe (ppm)	Mn (ppm)	Cr (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Co (ppm)	Ni (ppm)
S1	5296	448	246	30.4	44.2	55.4	27.5	42.2
S2	5448	514	258	31.3	46.5	52.8	28.6	44.1
S3	5601	586	312	34.6	48.3	55.8	29.5	46.3
S4	5753	621	319	36.2	48.5	67.3	28.6	47.2
S5	5906	730	342	30.2	47.4	145.0	28.4	91.2
S6	6032	760	520	29.6	54.2	160.0	39.8	145.8
S7	5984	732	456	32.7	52.6	80.6	32.2	57.2
S8	5826	685	421	31.2	51.5	89.3	39.3	47.5
S9	5754	635	395	31.6	58.9	122.4	32.4	51.2
S10	5978	712	347	26.4	70.8	240.0	27.0	102.2
S11	5988	734	481.8	37.2	59.6	256.0	22.8	121.4
S12	5876	648	461.6	26.4	32.2	48.6	24.4	105.4
S13	5970	714	345	28	81	235	25	99.3
Average	**5787**	**650**	**380.0**	**31.5**	**51.2**	**114.4**	**30.0**	**75.1**
Min	**5296**	**448**	**246**	**26.4**	**32.2**	**48.6**	**22.8**	**42.2**
Max	**6032**	**760**	**520**	**37.2**	**70.8**	**256**	**39.8**	**145.8**

Iron (Fe)

The higher concentration was observed in sample no 6 (6032ppm) and the lower concentration was in sample no 1 (5296ppm) the concentration of the sedimentary iron was not much variation except some samples. The concentration of sedimentary iron in this study not much higher than that reported other coastal areas of India and worldwide. The Iron in the study area was relatively low than the average continental crust values[31].The iron is mainly from the crustal weathering and can be converted to complex hydroxy compounds that may eventually precipitate[32]. This would lead the co-precipitation of other metals in the water column and so increase the concentration of many metals in sediments. The observed average Fe values in surficial bulk sediments of Cochin estuary is 4.39% [33]. A similar value of Fe has also been observed by Jayasree and Nair[34].

Manganese in the surface sediments off Cochin back water ranges from 448 to 760ppm the average concentrations of Mn are 650ppm. The highest concentration was recorded at sample no. 6 which is in estuarine transect. That estuarine sediment was deposited in to marine, the fine particles were goes in deeper zone. These fine particles contain relatively higher concentration of Mn. The lowest concentration was observed at sample no.1 where the coarser particles are dominant.

The results show that the chromium variation is from 246 to 520 ppm with an average of 380 ppm; the highest value was observed in sample no. 6 and the lowest at sample no.1. The chromium concentration is high in the sediment is mainly due to the adjacent estuary having high concentration of chromium. Jayaprakash et al.[35], have reported that the chromium concentration of 160 to 700 $\mu g.g^{-1}$ in estuary and pointed that the creek is much more contaminated by Cr due to both point and non-point sources. The concentration of Cr is reflecting the enrichment in study area. The distribution indicates a general increase towards the northern region. Low levels of chromium are found at estuaries. The high values are observed in the bar mouth region showing enrichment with respect to chromium. It may be concluded that the strong influence of freshwater modifies sediments to increase the chromium, as inferred from high values at the bar mouth.

Copper content in the study region varies from 26.4 to 37.2 ppm with an average of 31.5ppm. The highest concentration was observed in sample no 11 and the lowest was observed in sample no.10 & 12. The higher concentration of Cu in station 11 it may due to the organic matter and Fe-Mn oxyhydroxides produce simultaneous accumulation heavy metals in sediments. The Cu concentration is higher in all along the study area indicates the cu is mainly due to the anthropogenic input. This region is reported to contain high amount of particulate Cu [36]. Organic and sulphide - bound sediments characterize this region, which has a strong tendency to associate with copper[36-37].Hence organic association of copper seems to regulate the geochemistry of copper in this estuary. The concentrations in the overlying water do not exhibit any relative variability to explain the non- uniformity. Dissolved copper in the entire region is low and it varies from 0.3 to 37 μg/l. Concentrations of dissolved copper up to 37 μg/l have been reported for this region [36,38].

Analytical results showed that the lead varies from 32.2 to 70.8ppm with an average of 51.2ppm. The highest concentration of Pb in sample no.10 and the lowest was observed in sample no.12. However, the anthropogenic input of lead into this estuary seems to be insignificant, as very high concentrations are not encountered at any station. The mid -estuarine enrichment can be attributed to the sedimentation of metal –associated suspended solids and to flocculation due to increasing salinity. The residual fractions of lead in middle region are found to be an order of magnitude higher than those at less saline regions; even though the carbonate – bound lead is uniformly present [37].

The concentration of Zinc varies from 48.6 to 256ppm with an average of 114.4 ppm. The highest concentration was observed in sample no. 11 and the lowest observed in sample no.12. The high values are evidently due to external sources released from upstream. Earlier studies have also reported high concentrations of Zinc[39-40]. Zinc concentrations are the second highest values after iron in the mid estuarine region. The highest dissolved zinc value reported from this region during 1986 is 116 µg/l[40] and 89ug/l during 1991[36]. Shibu et al[41]., has estimated an accumulation of 80 tons of zinc in this part of the estuary. The current higher concentrations of zinc in Cochin backwater as compared with earlier studies clearly establish the anthropogenic source contributing to the enrichment of zinc in the sediment.

Cobalt is relatively scarce in the earth's crust. Cobalt occurs in di- and tri-valent state in rocks. Its migration in sea water and its geochemistry is almost similar to that of Ni. The Co concentrations are product of three main sources: i) Co fixed in the lattice position of clay minerals, ii) Co precipitated from overlying water column and iii) Co association with organic matter. The highest values are noticed in station no 6 and lowest value in station no 11. Nickel concentration in the study area varies from 42 to 145.8ppm with an average of 75.1ppm. The nickel concentration was relatively low with compared to other coastal and average sediment. The concentrations of different heavy metals with other Indian rivers and suggest that the Periyar River and Cochin estuary are showing heavy anthropogenic contamination. A large amount of effluents come from the industries. The heavy metal distribution in Cochin backwater is largely dependent upon two main components, the marine influence and fresh water discharge. The concentration of iron and zinc were high in all the stations compared to other metals. This may be the impact of zinc factory and nearby shipyard. The concentration of heavy metals in Cochin back waters were high, it may due to the low water concentration due to low fresh water discharge from Periyar River.

Distribution of foraminifera

Totally, 25 species are identified in this region (Table.2). Of which, the following species are widely distributed in this region namely, *Ammonia beccarri*, *A.tepida*, *Elphidium crispum*, *E.discoidale* and *E.advenum*. Furthermore based on foraminiferal distribution, it is observed that the following species are very rare and low in abundance namely *Amphistegina radiate, Textularia inflata*, *T.erlandi* and *Lagena leavis* due to heavy influx of freshwater in the estuarine area. Our findings also supported by Kameshwara Rao and Balasubramanium[42].

The foraminiferal in the estuary region is mainly transported from open sea due to tidal currents. The sampling station 1 to 5 shows very low species diversity. Only at the stations 6, 7, 9 & 10 records appreciable amount of species. All the remaining sampling stations are lesser amount of faunal assemblages. The estuary/sea bar mouth regions records appreciable amount of species. The variation in the total abundance of foraminifera in this region is mainly due the substrate as well as tidal current action. Further, due to the low salinity and freshwater influx from different rivers may control the foraminifer's abundance in this region. The remaining species are tolerant species from environmental degradation.

The tides in the area are of a mixed type, predominantly semidiurnal. The range of the tide is about 90 cm with a highest tide of 1.75 m. During SW monsoon months, the bottom sediments in the lagoon get stirred up and are transported from the lagoon to the sea. During NE monsoon and pre-monsoon periods, on the other hand, sediments get transported into the lagoon from the sea by the flood current, even though the ebb current is stronger than the flood current and the ebb current carries very little material with it. The velocity of the water currents depends on water depth, which at the stations covered inside the lagoon varies from 7.4 to 17m, 10m and in the near shore from 7.4 to 17m. The channel area has a depth of about 10.7m.

In the lagoon, sediments are mostly mud (silt + clay) while in the outer lagoon, i.e. near shore, they vary from muddy sediments to coarse sand and medium sand contents. The distribution of foraminifera appears to have a bearing on the type of bottom sediments.

Over all from the foraminifera distribution it is observed that station no 6, 7, 9 & 10 are more abundant in nature. The foraminiferal distribution are more in the harbour bar mouth area and near dredging area, where the samples are from the shallow open ocean off cochin harbour, where as the lowest values in the backwater may be it is transported in this backwater by the tidal currents.

The following species are dominated in the study region namely *A.beccarri*, *A.tepida*, *E.advenum*, *E.crispum* and *E.discoidale*. This assemblage is characteristic of modern-day inter-tidal and estuarine environments [43,44]. The overall dominance of *A.beccarri*, which is a cosmopolitan species with records world over (Murray)[45], and the associated taxa constituting the assemblages from these two trenches suggest a near shore inter-tidal environment possibly connected with the Arabian Sea. The presence of few tests of planktonic species such as *Globigerina bulloides* and *Globigerinoides ruber*, suggests that should have drifted in due to the action of tidal currents; both are essentially marine taxa and hence support the marine connection. Few tests of *A.dentata*, a nearshore species with short, blunt spines, also lend sufficient credentials to this interpretation. According to Ragothaman [46] and Rajeshwara Rao[47], tests of *A.dentata* with short, blunt spines are characteristic of nearshore waters; these should have drifted towards inland along with the globigerinids. The poor representation of miliolids could be attributed to reduced salinities, while the complete absence of arenaceous, agglutinated forms could be due to their breakdown either during processing as most of them are quite fragile, or due to the action of currents. The fine sediment accumulated at the bottom of cochin backwaters which also contains organic matter, favours the occurrence of stress-tolerant genera in this region namely Ammonia, Bolivina and Elphidium and other heterotrophic genera such as (Miliolinella and Quinqueloculina).

Based on the foraminiferal distribution, in the upper part of the estuary, species diversity are very rare in abundance namely *A.dentata*, *A.infata*, *Bolivina nobiles*, *Globigerina bulloides*, *Globigerina minardi* and *Legina laevis* due to the tidal fluctuation the species are distributed in this region.

In the middle estuary, the following species are distributed namely *A.beccarri*, *A.tepida*, *E.advenum*, *E.discoidale*, *E.cripsum* due to the mixing of estuarine and marine influence, the diversity is lesser in amount.

In the lower estuary near the seashore the species diversity is slightly higher than the middle estuary. Due to the salinity influence and the open ocean conditions the species namely *A.beccarri*, *A.tepida*, *E.advenum*, *E.cripsum*, *S.depressa* and *N.elongatum* are thriving in this region.

The distribution of foraminifera with respect to geochemical distribution are given in a Fig.6 to Fig.13. Fe concentration Vs total foraminifera shows positive correlation. In the same way Mn, Cr, Cu, Pb, Zn, Co and Ni are showed positive correlation. The positive correlation with foraminifera and trace elements indicates that the trace elements not directly affect the distribution of foraminifera. Further the distribution of species are stress tolerance species which may not affect in this region other than diversity.

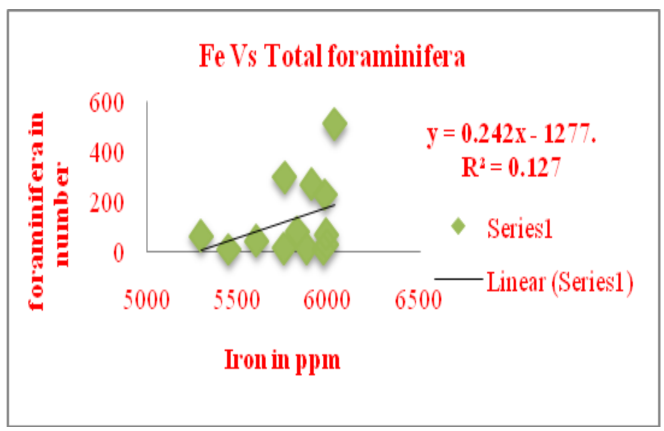

Fig 6 Scatter plots of Fe Vs Total foraminifera

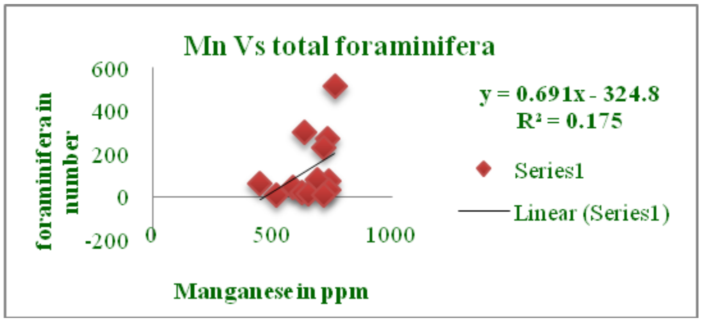

Fig 7 Scatter plots of Mn Vs Total foraminifera

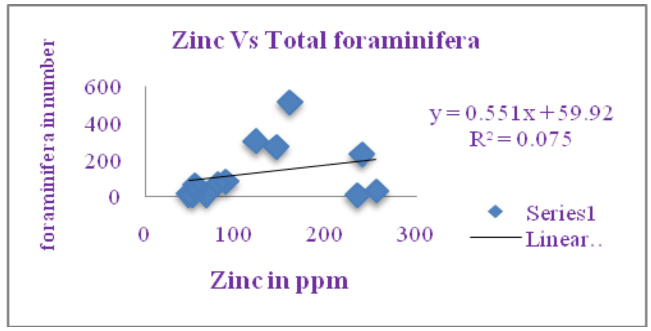

Fig 11 Scatter plots of Zn Vs Total foraminifera

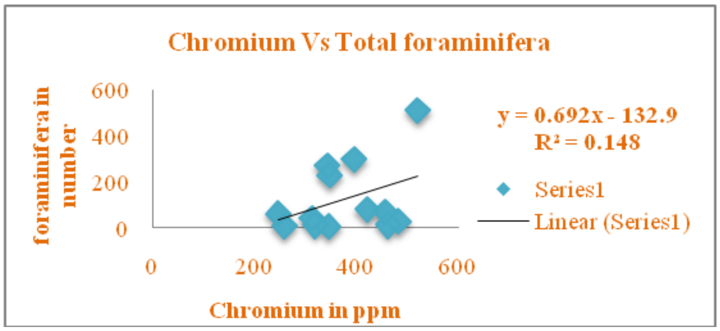

Fig 8 Scatter plots of Cr Vs Total foraminifera

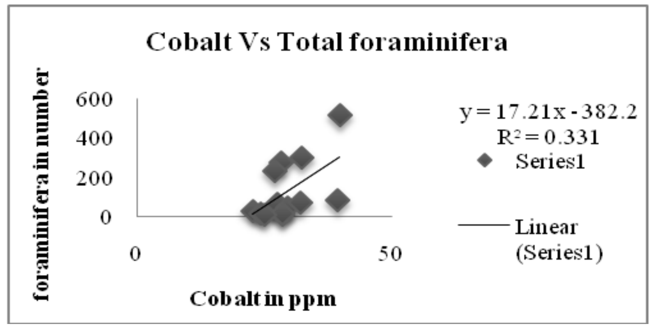

Fig 12 Scatter plots of Co Vs Total foraminifer

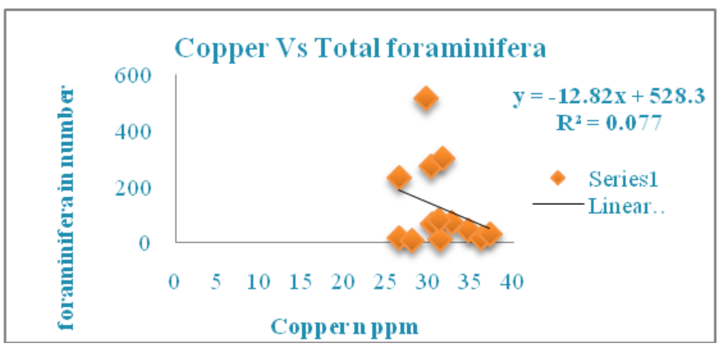

Fig 9 Scatter plots of Cu Vs Total foraminifera

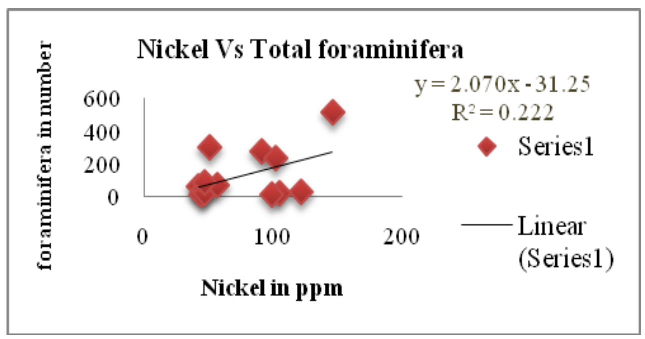

Fig 13 Scatter plots of Ni Vs Total foraminifera

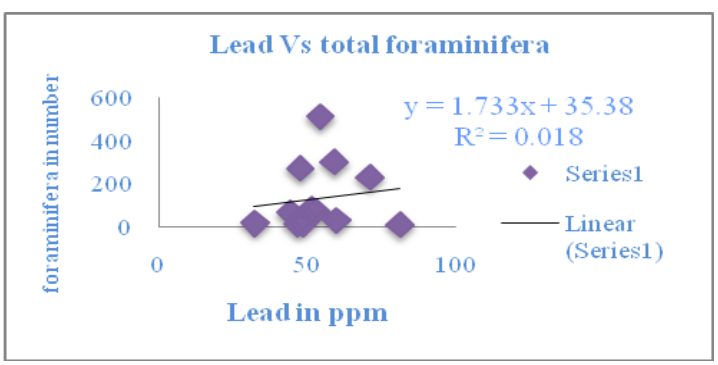

Fig 10 Scatter plots of Pb Vs Total foraminifera

Conclusion

Totally 13 surface sediment were collected from the Cochin backwaters. A total of 25 foraminiferal taxa belonging to 16 genera, 13 families, 10 super families, and 6 suborders have been identified. Sandy silt and Sand substrates have been predominantly found in the study area. The sand–silt-clay, organic matter and carbonate content studies clearly indicate the nature of deposition environments. From the overall distribution of the fauna in the present area, it may be observed that the Calcium carbonate, organic matter is the major controlling factors for the thriving of foraminifera fauna throughout the year.

From the total number of species, *A.beccarri*, *A.tepida*, *E.crispum* and *E.advenum* shows a prolific abundance in this region in the lower estuary. The total distribution of foraminifera is higher at bar mouth region than the estuarine regions. The occurrence of species in the upper estuarine region is mainly due to transport by tidal currents. The heavy metal distribution in Cochin backwater is largely dependent upon two main components, the marine influence and fresh water discharge. The concentration of iron and zinc were high in all the stations compared to other metals. The lower diversity of foraminifera in this region may be due to the freshwater influx and shallow depths leads to unfavorable environments for foraminifera population.

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